**Chapter 9 Section 3: Actions at Plate Boundaries**

**Key Concepts**

* [What is seafloor spreading?](javascript:openCrossRef('../ch9/ch9_s3_1.html%23lnk258.4'))
* [What is a subduction zone?](javascript:openCrossRef('../ch9/ch9_s3_2.html%23lnk261.1'))

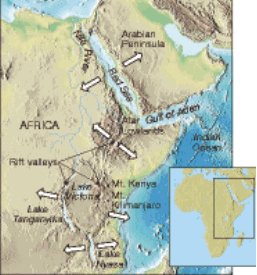
**Vocabulary**

* [trench](javascript:openCrossRef('../ch9/ch9_s3_2.html%23lnk261.2'))
* [continental volcanic arc](javascript:openCrossRef('../ch9/ch9_s3_2.html%23lnk261.5'))
* [volcanic island arc](javascript:openCrossRef('../ch9/ch9_s3_2.html%23lnk262.1'))
* [oceanic ridge](javascript:openCrossRef('../ch9/ch9_s3_1.html%23lnk258.4'))
* [rift valley](javascript:openCrossRef('../ch9/ch9_s3_1.html%23lnk258.4'))
* [seafloor spreading](javascript:openCrossRef('../ch9/ch9_s3_1.html%23lnk259.1'))
* [subduction zone](javascript:openCrossRef('../ch9/ch9_s3_2.html%23lnk261.2'))

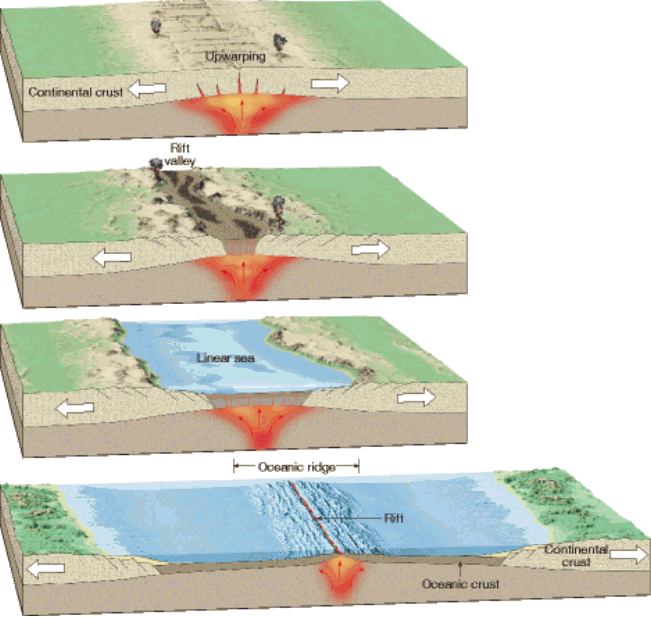
**Divergent Boundaries**

Most divergent plate boundaries are located along the crests of oceanic ridges. These plate boundaries can be thought of as *constructive plate margins* because this is where new oceanic lithosphere is generated. Look again at the divergent boundary in Figure 7A on page 255. As the plates move away from the ridge axis, fractures are created. These fractures are filled with molten rock that wells up from the hot mantle below. Gradually, this magma cools to produce new slivers of seafloor. Spreading and upwelling of magma continuously adds oceanic lithosphere between the diverging plates.

**Oceanic Ridges and Seafloor Spreading**

Along well-developed divergent plate boundaries, the seafloor is elevated, forming the [**oceanic ridge**](javascript:openGlossaryWnd('e_ga_06_oceanicridge')). The system of ocean ridges is the longest physical feature on Earth’s surface, stretching more than 70,000 kilometers in length. This system winds through all major ocean basins like the seam on a baseball. The term *ridge* may be misleading. These features are not narrow like a typical ridge. They are 1000 to 4000 kilometers wide. Deep faulted structures called [**rift valleys**](javascript:openGlossaryWnd('e_ga_06_riftvalley')) are found along the axes of some segments. As you can see in Figure 9, rift valleys and spreading centers can develop on land, too.

[**Seafloor spreading**](javascript:openGlossaryWnd('e_ga_06_seaflrsprdng')) **is the process by which plate tectonics produces new oceanic lithosphere.** Typical rates of spreading average around 5 centimeters per year. These rates are slow on a human time scale. However, they are rapid enough so that all of Earth’s ocean basins could have been generated within the last 200 million years. In fact, none of the ocean floor that has been dated is older than 180 million years.

**Figure 9** The East African rift valleys may represent the initial stages of the breakup of a continent along a spreading center. **A** Rising magma forces the crust upward, causing numerous cracks in the rigid lithosphere. **B** As the crust is pulled apart, large slabs of rock sink, causing a rift zone. **C** Further spreading causes a narrow sea. **D** Eventually, an ocean basin and ridge system is created. **Relating Cause And Effect** What causes the continental crust to stretch and break?

**Continental Rifts**

When spreading centers develop within a continent, the landmass may split into two or more smaller segments. Examples of active continental rifts include the East African rift valley and the Rhine Valley in Northwest Europe.



**Figure 10 East African Rift Valley** This valley may be where the African continent is splitting apart. **Interpreting Diagrams** What stage in the drawings on page 259 does this photograph show?

The most widely accepted model for continental breakup suggests that forces that are stretching the lithosphere must be acting on the plate. These stretching forces by themselves are not large enough to actually tear the lithosphere apart. Rather, the rupture of the lithosphere is thought to begin in those areas where plumes of hot rock rise from the mantle. This hot-spot activity weakens the lithosphere and creates domes in the crust directly above the hot rising plume. Uplifting stretches the crust and makes it thinner, as shown in Figure 9A. Along with the stretching, faulting and volcanism form a rift valley, as in Figure 9B.

The East African rift valley, shown in Figure 10, may represent the beginning stage in the breakup of a continent. Large mountains, such as Kilimanjaro and Mount Kenya, show the kind of volcanic activity that accompanies continental rifting. If the stretching forces continue, the rift valley will lengthen and deepen, until the continent splits in two. At this point, the rift becomes a narrow sea with an outlet to the ocean, similar to the Red Sea. The Red Sea formed when the Arabian Peninsula rifted from Africa about 20 million years ago. In this way, the Red Sea provides scientists with a view of how the Atlantic Ocean may have looked in its infancy.

**Convergent Boundaries**

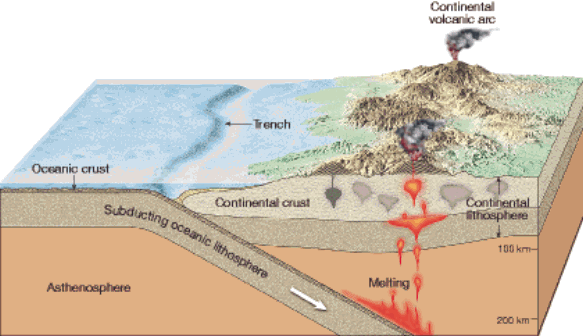
Although new lithosphere is constantly being added at the oceanic ridges, our planet is not growing larger. Earth’s total surface area remains the same. How can that be? To accommodate the newly created lithosphere, older portions of oceanic plates return to the mantle along convergent plate boundaries. Because lithosphere is “destroyed” at convergent boundaries, they are also called *destructive plate margins*. As two plates slowly converge, the leading edge of one is bent downward, allowing it to slide beneath the other. Destructive plate margins where oceanic crust is being pushed down into the mantle are called [**subduction zones**](javascript:openGlossaryWnd('e_ga_06_subdctionzon')). The surface feature produced by the descending plate is an ocean [**trench**](javascript:openGlossaryWnd('e_ga_06_trench')), as shown in Figure 11. **A subduction zone occurs when one oceanic plate is forced down into the mantle beneath a second plate.**

Convergent boundaries are controlled by the type of crust involved and the forces acting on the plate. Convergent boundaries can form between two oceanic plates, between one oceanic plate and one continental plate, or between two continental plates.

**Oceanic-Continental**

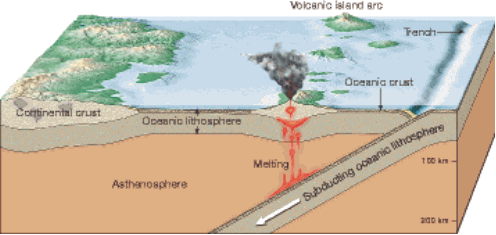
When the leading edge of a continental plate converges with an oceanic plate, the less dense continental plate remains floating. The denser oceanic slab sinks into the asthenosphere. When a descending plate reaches a depth of about 100 to 150 kilometers, some of the asthenosphere above the descending plate melts. The newly formed magma, being less dense than the rocks of the mantle, rises. Eventually, some of this magma may reach the surface and cause volcanic eruptions.

The volcanoes of the Andes, located along western South America, are the product of magma generated as the Nazca plate descends beneath the continent. Figure 11 shows this process. The Andes are an example of a [**continental volcanic arc**](javascript:openGlossaryWnd('e_ga_06_continntvlca')). Such mountains are produced in part by the volcanic activity that is caused by the subduction of oceanic lithosphere.



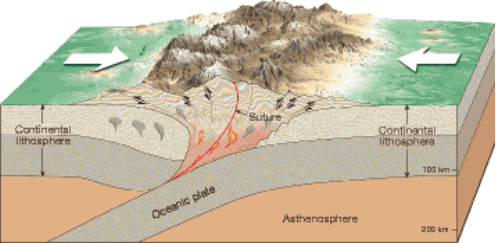
**Figure 11 Oceanic-Continental Convergent Boundary** Oceanic lithosphere is subducted beneath a continental plate. **Inferring** Why doesn’t volcanic activity occur closer to the trench?

**Oceanic-Oceanic**

When two oceanic slabs converge, one descends beneath the other. This causes volcanic activity similar to what occurs at an oceanic-continental boundary. However, the volcanoes form on the ocean floor instead of on a continent, as shown in Figure 12. If this activity continues, it will eventually build a chain of volcanic structures that become islands. This newly formed land consisting of an arc-shaped chain of small volcanic islands is called a [**volcanic island arc**](javascript:openGlossaryWnd('e_ga_06_volcanislarc')). The Aleutian Islands off the shore of Alaska are an example of a volcanic island arc. Next to the Aleutians is the Aleutian trench.

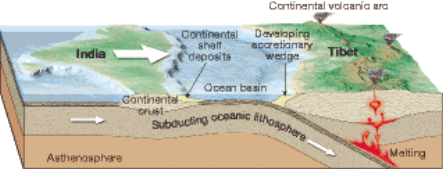
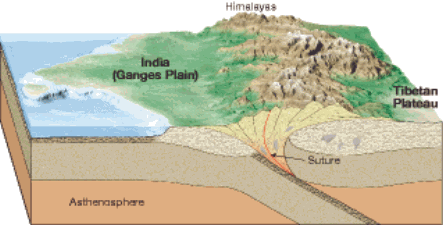
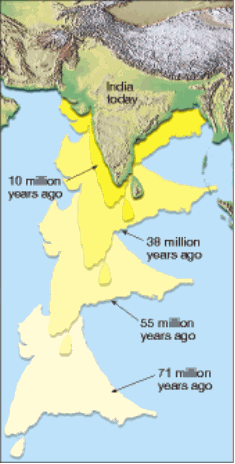
**Figure 12 Oceanic-Oceanic Convergent Boundary** One oceanic plate is subducted beneath another oceanic plate, forming a volcanic island arc. **Predicting** What would happen to the volcanic activity if the subduction stopped?

**Continental-Continental**

When an oceanic plate is subducted beneath continental lithosphere, a continental volcanic arc develops along the margin of the continent. However, if the subducting plate also contains continental lithosphere, the subduction eventually brings the two continents together, as shown in Figure 13. Continental lithosphere is buoyant, which prevents it from being subducted to any great depth. The result is a collision between the two continents, which causes the formation of complex mountains such as the Himalayas in South Asia.

**Figure 13 Continental-Continental Convergent Boundary** Continental lithosphere cannot be subducted because it floats. The collision of two continental plates forms mountain ranges.

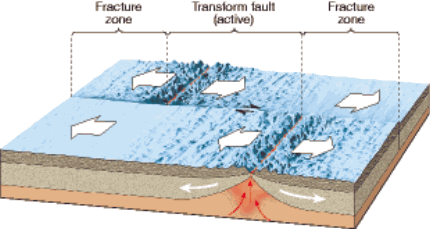
Before continents collide, the landmasses involved are separated by an ocean basin. As the continents move toward each other, the seafloor between them is subducted beneath one of the plates. When the continents collide, the collision folds and deforms the sediments along the margin as if they were placed in a giant vise. A new mountain range forms that is composed of deformed and metamorphosed sedimentary rocks, fragments of the volcanic arc, and possibly slivers of oceanic crust.

This kind of collision occurred when the subcontinent of India rammed into Asia and produced the Himalayas, as shown in Figure 14. During this collision, the continental crust buckled and fractured. Several other major mountain systems, including the Alps, Appalachians, and Urals, were also formed as a result of continental collisions.

**Figure 14 A** The leading edge of the plate carrying India is subducted beneath the Eurasian plate. **B** The landmasses collide and push up the crust. **C** India’s collision with Asia continues today.

**Transform Fault Boundaries**

The third type of plate boundary is the transform fault boundary. **At a transform fault boundary, plates grind past each other without destroying the lithosphere.** Most transform faults join two segments of a mid-ocean ridge, as shown in Figure 15. These faults are present about every 100 kilometers along the ridge axis. Active transform faults lie between the two offset ridge segments. The seafloor produced at one ridge axis moves in the opposite direction as seafloor is produced at an opposing ridge segment. So between the ridge segments these slabs of oceanic crust are grinding past each other along a transform fault.



**Figure 15** A transform fault boundary offsets segments of a divergent boundary at an oceanic ridge.

Although most transform faults are located within the ocean basins, a few cut through the continental crust. One example is the San Andreas Fault of California. Along the San Andreas, the Pacific plate is moving toward the northwest, past the North American plate. If this movement continues, that part of California west of the fault zone will become an island off the west coast of the United States and Canada. It could eventually reach Alaska. However, a more immediate concern is the earthquake activity triggered by movements along this fault system.

**SECTION 9.3 Assessment**

**Reviewing Concepts**

(1) What is seafloor spreading?

(2) What is a subduction zone? What types of plate boundaries have

subduction zones?

(3) Describe the process that occurs when continents converge.

(4) What actions of plate boundaries cause the destruction of the

lithosphere?

**Critical Thinking**

(5) **Drawing Conclusions** What evidence supports the idea that the Earth

is neither growing nor shrinking in size?

(6) **Relating Cause And Effect** During the collision between two continents,

why doesn’t a subduction zone form?

(7) **Predicting** How will the angle at which an oceanic plate is subducted

affect the distance from the volcanic arc to the trench?